

# Auricular Reconstruction Using Porous Polyethylene Implant Technique



Scott Stephan, MD<sup>a,\*</sup>, John Reinisch, MD<sup>b</sup>

## KEYWORDS

• Auricular reconstruction • Porous polyethylene • Implant • Ear

## KEY POINTS

- Porous high-density polyethylene as an alloplast in microtia reconstruction offers an excellent framework for auricular reconstruction.
- Advantages include earlier reconstruction, fewer procedures, avoidance of donor site morbidity, shorter learning curve, and improved size and contour match.
- Results ultimately depend on soft tissue envelope, and choice of technique is best decided according to surgeon expertise and patient preference.

## INTRODUCTION

Creation of an external ear remains one of the most challenging dilemmas for reconstructive surgeons. Between the thin soft tissue envelope surrounding an intricate, flexible framework projecting off the mastoid, success in recreating native anatomy depends as much on the patient's soft tissue characteristics as it does on surgical technique.

The choice of material for creating the architecture and framework of the ear has long been a topic of debate and continues to evolve. Staged autologous cartilage reconstruction remains the most widely used technique in microtia repair,<sup>1</sup> but many surgeons have turned to alloplasts to avoid donor site morbidity, begin reconstruction at an earlier age, reduce the number of total surgeries, increase the predictability of their results, improve on the inherent structural limitations of

autologous rib, and to tailor to individual patients' needs (ie, low-lying hairline, bilateral microtia). This article broadly discusses the considerations for alloplast-based ear reconstruction, details a series of evolving technical advancements, and expands on the description of the surgical procedure outlined in the authors' previous work.<sup>2</sup>

## AURICULAR ALLOPLASTS

The ideal alloplast for auricular reconstruction would be cost-effective, safely implantable, resistant to infection and repeated trauma, and be easily customized to approximate the contralateral native ear.

Since 1891, more than 40 different framework materials have been described in the ear, including alloplasts such as ivory, wire mesh, nylon, and silicone.<sup>3,4</sup> Silicone was initially viewed as a promising prospect, particularly for its ability to mimic

Disclosure: The authors have nothing to disclose.

<sup>a</sup> Department of Otolaryngology, Head and Neck Surgery, Vanderbilt University Medical Center, 7th Floor Medical Center East, South Tower, 1211 Medical Center Drive, Nashville, TN 37232, USA; <sup>b</sup> Department of Surgery, University of Southern California, 1450 San Pablo Street, Healthcare Consultation Center 4 Suite 6200, Los Angeles, CA 90089, USA

\* Corresponding author.

E-mail address: Stephan@vanderbilt.edu

Facial Plast Surg Clin N Am 26 (2018) 69–85

<https://doi.org/10.1016/j.fsc.2017.09.009>

1064-7406/18/© 2017 Elsevier Inc. All rights reserved.

the flexibility and structure of native auricular cartilage, but a high extrusion rate when placed under thin skin flaps was ultimately problematic.<sup>5</sup>

First described for partial auricular reconstruction by Berghaus and colleagues<sup>19</sup> in 1983, porous high-density polyethylene (pHDPE), originally marketed as Medpor (Stryker, Kalamazoo, MI) has a long record of successful, safe use as an implantable framework. Other companies now offer similar pHDPE ear implants, such as Omnipore (Matrix Surgical USA, Atlanta, GA) and Su-Por (Poriferous, Newnan, GA). pHDPE is a modestly flexible, biocompatible material made of high-density polyethylene with interconnected pores (100–200  $\mu\text{m}$  diameter) that show structural stability and the ability to support soft tissue ingrowth.<sup>6,7</sup> As a porous material, this facilitates collagen deposition and vascular ingrowth, which in turn protects against extrusion and infection, and allows systemic drug delivery to the implant.<sup>8</sup> Structurally, pHDPE is robust enough to withstand the repeated microtrauma expected of an ear, but is easily shapeable with a scalpel, and separate pieces may be soldered together with high-temperature cautery. The authors' experience with customization with drill technique is reviewed later.

The basic paradigm for microtia reconstruction using a pHDPE implant involves implantation of a fused two-piece framework, completely covered with a large temporoparietal fascia (TPF) flap and resurfaced with a mixture of skin grafts and local flaps. This procedure has been described as both single stage<sup>5</sup> and multistage.<sup>4,9–11</sup>

### CONSIDERATIONS FOR HIGH-DENSITY POROUS POLYETHYLENE

One advantage of alloplast reconstruction is the avoidance of a chest wall donor site. Because the quantity and quality of the patient's rib cartilage is not a factor, patients do not need to wait for chest wall maturity for costal cartilage harvest, and may undergo reconstruction at an earlier age. The youngest child implanted in the authors' experience was 2.5 years old, with preferred timing between 3 and 6 years of age. pHDPE is available as a preformed 2-piece implant, and a straightforward technique allows a shorter learning curve for new surgeons. Modern modifications to the procedure have resulted in comparable complication rates with autologous cartilage, and cosmetic outcomes can be excellent in experienced hands.<sup>4,12</sup> Microtia reconstruction with porous polyethylene may be performed after or at the same time as canal atresia surgery if the patient is deemed a suitable candidate for canalplasty.

Thus, patients can have their atresia and microtia reconstructions completed in a single stage before entering primary school, which is an important period of cognitive awareness and self-concept.<sup>13–15</sup> There are also aesthetic and technical considerations as to why pHDPE auricular reconstruction is better earlier than later in the authors' experience: the TPF flap used to cover the implant is the blood supply to the overlying hair follicles and becomes thicker as the child approaches late adolescence to teenage years, perhaps as a factor of increased hair density and caliber with puberty. When done at an early age, the TPF is thin and more pliable, allowing it to easily contour to the architecture of the implant under negative pressure, yielding superior detail. There is significantly less bleeding and better visualization of surgical planes in younger children than in adolescents and adults. Also, the dermal layer of the harvested full-thickness skin grafts used to cover the TPF flap is also inherently thinner.

Although salvage surgery using autologous rib with adjunctive procedures has been described,<sup>16,17</sup> it is not common and the outcomes are widely variable. In contrast, the pHDPE implant-based approach is versatile; it serves as an excellent primary option in many cases or can be used as salvage surgery after failed autologous rib, burn cases, auricular avulsion, or situations of significant scarring of the mastoid skin area, provided that a well-vascularized fascial flap is still available for framework coverage.

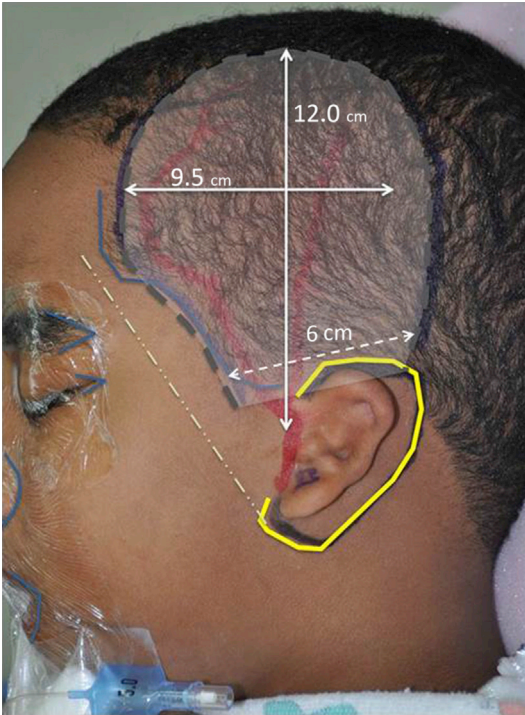
### TECHNIQUE

The authors' reconstructive approach is described later, adapted from the single-stage technique first described by the senior author and modified over the years to the current iteration.<sup>3,5</sup> The emphasis is on microtia reconstruction, but the principles remain generalized for auricular reconstruction broadly.

### PREP

The patient is orotracheally intubated and the bed rotated 180°. Hair over the temporoparietal area on the surgical side is shaved to allow proper Doppler identification of the vascular anatomy. The course of the superficial temporal artery is mapped using vascular Doppler and a permanent skin marker. The anterior and posterior branches of the superficial temporal artery (STA) are marked and, if possible, any superior anastomosing arcade between the 2 ends distally (**Fig. 1**).

It can be helpful to identify the main trunk of the STA as it courses near the auricular remnant. In



**Fig. 1.** Identification of landmarks and flap design. Yellow lines indicate skin incisions. Vertical dimension of the TPF flap is measured from the proposed superior border of the neo-external auditory canal extending vertically toward the vertex of the scalp. The anterior/posterior dimension is slightly narrower, extending to the temporal hairline to incorporate the anterior branch of the STA (demarcated in red). The base of the TPF flap is kept wide to maintain venous drainage in the mastoid region. (From Owen S, Wang T, Stephan S. Alloplastic reconstruction of the microtic ear. *Operat Tech Otolaryngol Head Neck Surg* 2017;28(2):98; with permission.)

severe cases of microtia, the vessel can originate from the post-auricular artery rather than being the terminal branch of the external carotid vessel. In these cases the vessel begins behind the lobe and courses underneath the microtic cartilage putting the vessel in danger during removal of the cartilage remnant.

The anticipated course of the frontal branch of the facial nerve is also delineated using the Pitanguy line principle, using the mastoid tip as the inferior point of reference in place of the lobule.

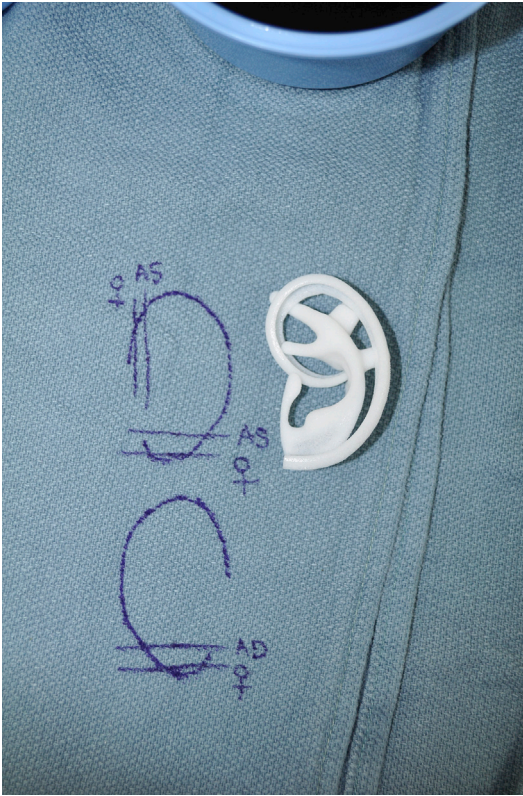
Using a piece of radiograph film (or the clear plastic guard from a surgical face mask), the position and size of the contralateral normal ear are marked relative to the oral commissure, nasal alar groove, orbitomalar groove, lateral canthus, and lateral brow **Fig. 2**. The radiograph film can be sterilized for later use on the field, or the plastic mask sheet can be covered by sterile translucent



**Fig. 2.** Radiograph film tailored to dimensions of the contralateral ear with surface landmarks of the lateral brow, lateral canthus, malar-orbital groove, alar-facial groove, and oral commissure used to orient the new ear on the opposite side with respect to location and axis. Intra-auricular details such as the superior and inferior crura as well as the shape of the conchal bowl are cut as single lines through the film.

dressings. The dimensions of the new ear are based on the contralateral normal ear, taking into consideration the patient's age at the time of surgery and anticipated future growth. In addition, notes are taken of specific details and unique features found on the normal ear that will be customized during the molding and soldering of the implant later in the procedure.

Careful preoperative assessment of the patient's age, contralateral ear dimensions in the setting of unilateral microtia, as well as the dimensions of their gender-matched parent's ear are essential to achieving symmetry between the reconstructed pHDPE ear and the normal ear. The pHDPE will not increase in size so an adult-sized ear must be created at the time of surgery. In a forensic study of normative data for ear growth in more than 800 patients, at 4 to 5 years of age, ear vertical length was approximately 90% (girls) and 84% to 86% (boys) of the relevant values recorded in individuals 18 to 30 years old.<sup>18</sup> Therefore, adding a 10% to 15% increase in height from the contralateral ear in a 4-year-old patient (about 5–7 mm) is a reasonable estimation; using dimensions from the parents can also be a double check (**Fig. 3**). A case example of a boy 3 years and 2 months old who underwent pHDPE microtia reconstruction with modest adjustment in size for future growth shows the ability to accurately compensate for this dynamic even in very young patients (**Fig. 4**).

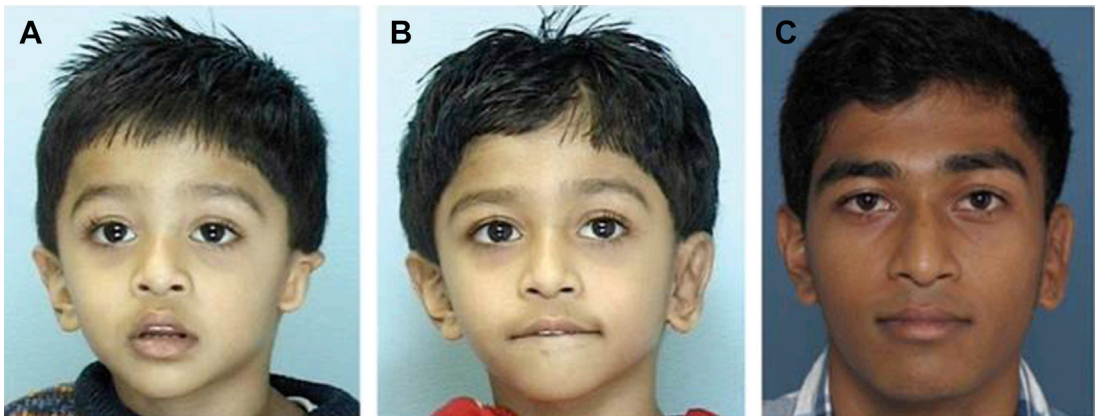


**Fig. 3.** For a 7-year-old girl with unilateral left microtia reconstruction, measurements of the normal right ear (AD) as well as that of her mother's right ear are shown at the bottom of the image. Using this information, the proposed left ear (AS) size is then designed and the pHDPE implant customized to what will be her predicted adult-sized ear.

Likewise, a perfectly symmetric ear that is moderately malpositioned may be an even greater disfigurement and distraction than the original

microtia. Of the facial landmarks used for orientation, the lateral brow, lateral canthus, malar-orbital groove, and alar groove are the most trustworthy in patients with some degree of craniofacial microsomia, because the first and second branchial arch malformations disproportionately affect the lower facial skeleton. The patient's eyes, nose, and mouth are kept visible but covered with an occlusive transparent dressing to remain out of the sterile field. The head is prepped with betadine solution, and the auricular remnant, incisions, and skin graft donor sites injected with local anesthetic.

The scalp incisions used to approach the TPF flap elevation are varied, with multiple approaches described. The authors favor elevation of the flap entirely from below, using only the incision in the postauricular area of the microtic ear corresponding with the position of the new helical rim. This incision is made on the postauricular component of the portion of the ear that is present (**Fig. 5**). In patients with low-set hairlines, up to a third or half of this incision along its superior margin may be in hair-bearing skin. Whatever component of the anteriorly based mastoid skin flap contains hair is discarded. Therefore, the surgeon does not have to compromise either the placement of the implant or the final aesthetics of a hairy ear based on the patient's preoperative mastoid hairline position. To improve exposure, a curvilinear horizontal incision over the superior portion of the TPF flap can be added; this additional incision can help visualize the distal most portion of the anterior branch as it travels just posterior to the frontal branch of facial nerve. It can also be helpful in harvesting the distal flap to obtain the recommended length. These two approaches allow adequate access to elevate a wide TPF flap with a lighted retractor or head light.



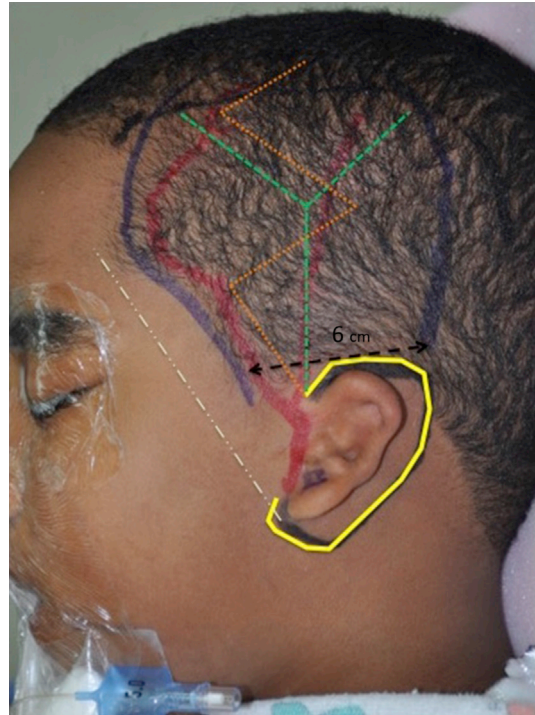
**Fig. 4.** (A) Child seen before left ear reconstruction at 3 years and 2 months; (B) 10 months after left ear reconstruction with modest adjust in vertical height; (C) same patient seen at 20 years of age with good interaural height symmetry. (From Reinisch J. Ear reconstruction in young children. *Facial Plast Surg* 2015;31:602; with permission.)



**Fig. 5.** Elevation of the TPF flap is done through the postauricular incision only using needle tip electrocautery and a headlight or lighted retractor.

Other approaches include a Y incision extending superiorly from the mastoid area, as well as a large Z to expose the TPF. Each of these allow much better visualization and access to the fascia but carry the risk of patchy alopecia near incisional bifurcations or the apex of a triangular flap. The TPF provides vascular perforators to the dermal plexus that supply the follicles; any incisions through the dermal plexus can compromise perfusion through this layer from the occipital, supraorbital, and contralateral STA vascular watersheds (**Fig. 6**).

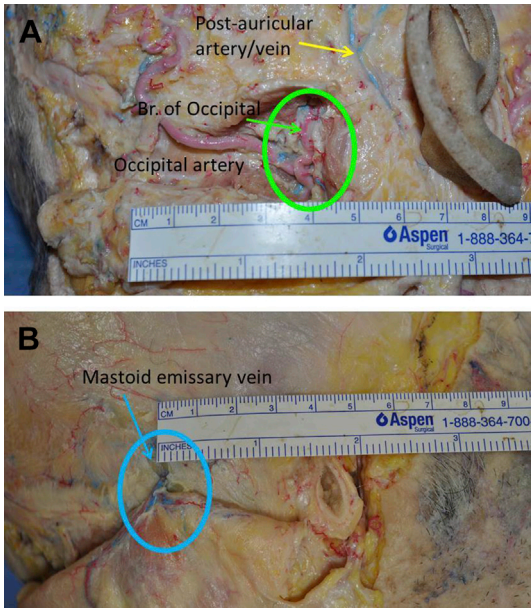
Next, the remnant microtic cartilage is excised. This stage is performed by meticulous elevation of a very thin anteriorly based skin flap off the microtic cartilage, then coming under the cartilage mass and excising it. This flap frequently requires additional thinning when laying onto the pHDPPE framework for optimal definition. The inferior portion of this flap typically has the lobule remnant attached to it initially. For improved soft tissue coverage, particularly with a malpositioned lobule, this flap may be amputated and used as a free skin graft. Amputation allows for improved ability to thin the skin; reserves that high-quality skin for use in the most aesthetically important areas (helical rim, scaphoid, antihelical fold (AHF) fossa triangularis) instead of the conchal bowl, which can tolerate darker skin if needed; and provides more flexibility in orientation. When removing the remnant microtic cartilage from the mastoid area, care must be taken not to injure a potentially anomalous course of the main trunk of the superficial temporal vascular pedicle that aberrantly courses under the cartilage. This possibility can be particularly relevant when removing excessive mastoid soft tissue down to the periosteal layer to create a deeper conchal bowl or in the setting of combined atresia-microtia cases in which the otologist requires subperiosteal elevation to expose the mastoid bone. Careful Doppler assessment of the vascular pedicle's trajectory



**Fig. 6.** Alternative scalp incisions. The Y or zigzag incision can be used for better access and visualization, but carry a higher risk for focal alopecia. (From Owen S, Wang T, Stephan S. Alloplastic reconstruction of the microtic ear. *Operat Tech Otolaryngol Head Neck Surg* 2017;28(2):99; with permission.)

immediately before surgery can help identify these anomalous cases.

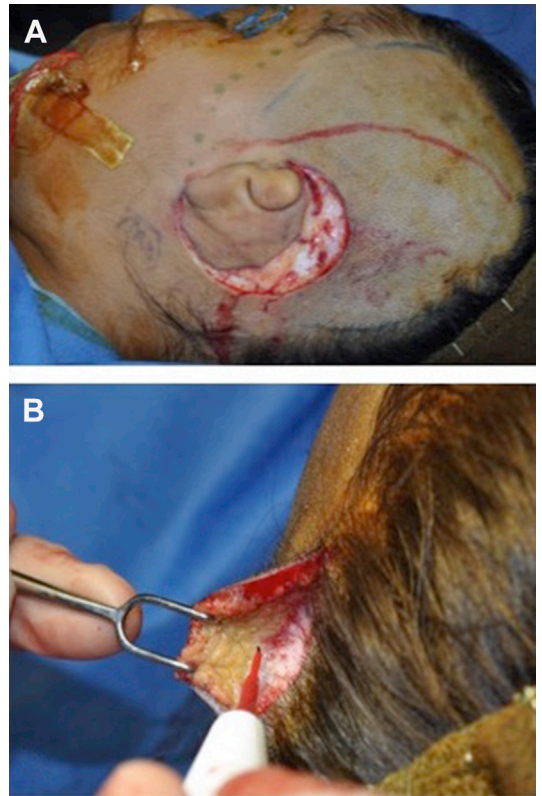
Using the superior scalp incision, the temporo-parietal area is widely undermined in a subcutaneous plane, with care taken not to violate either the TPF beneath or the hair follicles above. Once widely exposed, an inferiorly based TPF flap measuring approximately  $10.5 \times 13.0$  cm is incised and elevated off the underlying deep temporal fascia (investing temporalis muscle) and the periosteum in the portion superior to the temporal line. Approximately one-third of the flap is superior to the temporal line, making it in practice a combination TPF extended by superficial parietal galeal aponeurosis. The base of the flap is kept wide (approximately 6 cm) to maximize inclusion of secondary vascular supply from the postauricular artery, early branches off the occipital artery, and the mastoid emissary vein. Although preserving every bit of the secondary vascular supply from this mastoid region is not always possible, every attempt is made to ensure the flap is as robust as possible with a redundant vascular supply (**Fig. 7**). Care is taken to preserve and include both the anterior and posterior branches



**Fig. 7.** Latex-injected cadaver dissections show the secondary vascular supply to the extended TPF flap from the mastoid region. If the base of the TPF flap is kept wide (~6 cm), several other vascular structures can be included in the mastoid area. (A) The postauricular artery and vein are located within 4 cm of an area posterior to the ear canal, as well as early branches (Br.) off the transverse portion of the occipital artery that course superiorly to the mastoid region. (B) Mastoid emissary vein is large, drains intracranial to the sigmoid sinus, and can often be incorporated if the flap base is kept wide.

of the superficial temporal artery, using electrocautery on a low setting to avoid thermal damage to the microvasculature. It is critical to include the loose areolar tissue on the deep surface of the TPF. This loose tissue will rest against the under-surface of the skin grafts and permit the skin to glide over the underlying structure, resisting soft tissue trauma and implant exposure. The flap is then reflected inferiorly through the superior portion of the posterior auricular incision (**Figs. 8 and 9**).

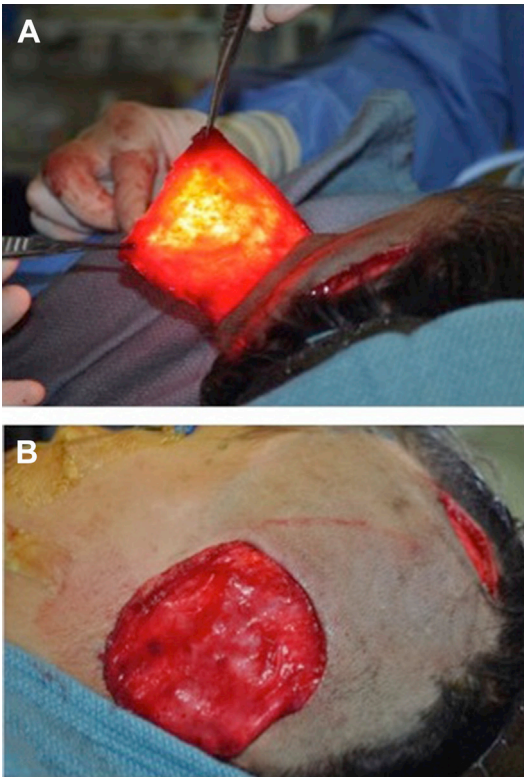
Next, the 2-piece pHDPPE framework is sculpted and fused. The 2 separate implant pieces are placed in a 60-mL syringe of betadine, and placed under negative pressure to push antiseptic solution through the entire implant, not just coating the surface. The implant is tailored to the appropriate dimensions to match the contralateral ear. This process may be aided with the radiograph film template made from the contralateral ear. The pHDPPE implant may be customized intraoperatively to appropriately mirror the patient's native anatomy. The implants are easily carved



**Fig. 8.** (A) Postauricular incision made first and cartilage remnant removed leaving thin anteriorly based skin flap. (B) TPF flap elevation requires meticulous separation of subcutaneous fat away from superficial surface of TPF. (From Owen S, Wang T, Stephan S. Alloplastic reconstruction of the microtic ear. *Operat Tech Otolaryngol Head Neck Surg* 2017;28(2):99; with permission.)

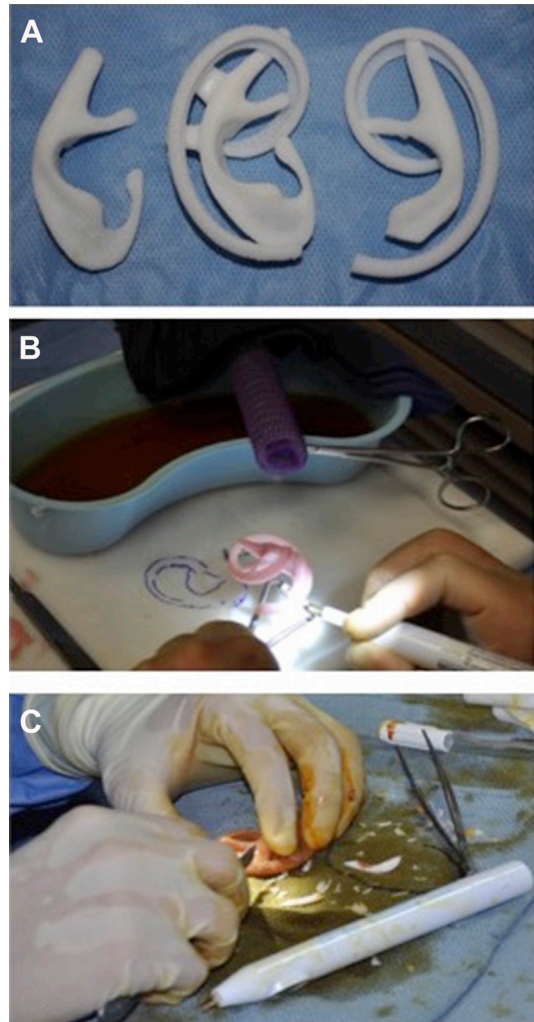
with a scalpel, and the 2 preformed components are then fused with high-heat ophthalmic cautery. The tragal extension and some portion of the lobule are routinely amputated in microtia cases; for auricular avulsion, anotia, or other complete ear reconstructions, the entire lobule can be preserved. The tragal portion is brittle and difficult to wrap with the TPF flap without blunting the bowl. The amputated pieces can be cut into many smaller fragments used to reinforce the implant. In particular, the union of the superior and inferior crura of the AHF to the helical rim requires reinforcement to avoid fracture and subluxation. Other modifications to the pHDPPE framework can also be done, such as deepening of the conchal bowl and making the uniform helical rim irregular to provide a more natural appearance, as needed (**Figs. 10 and 11**).

Before placement of the implant, 2 flat suction drains are placed through the posterior mastoid



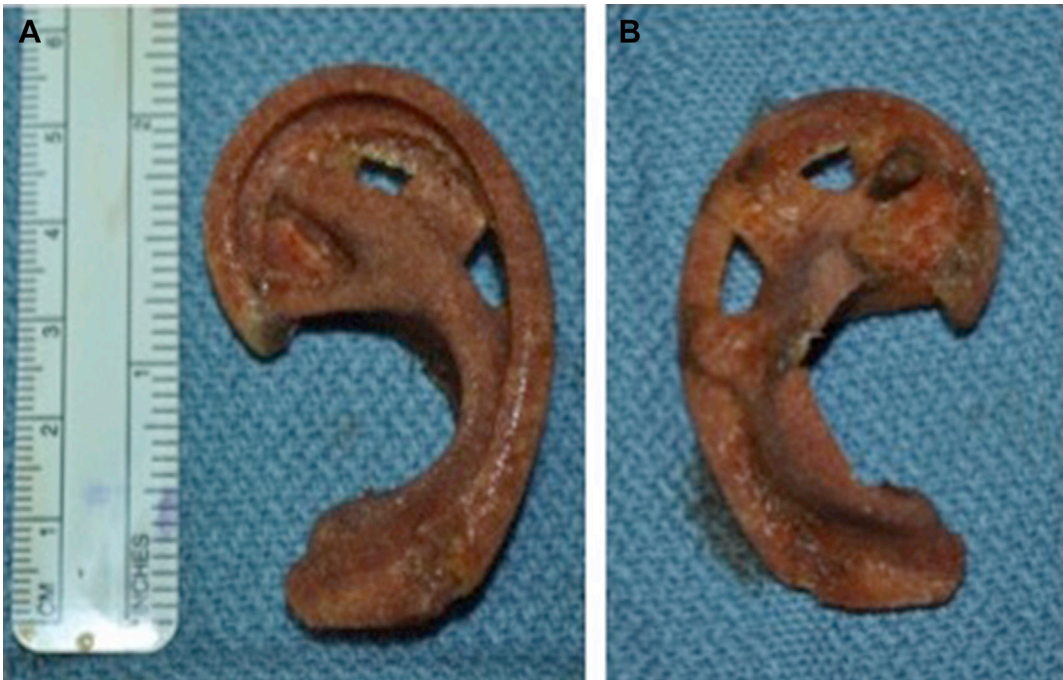
**Fig. 9.** (A) Vessels within thin TPF flap can be identified by transillumination. (B) TPF flap is delivered through a bipedicle scalp flap to the mastoid area. (From Owen S, Wang T, Stephan S. Alloplastic reconstruction of the microtic ear. *Operat Tech Otolaryngol Head Neck Surg* 2017;28(2):100; with permission.)

hair-bearing skin, with one deep to the pHDPE construct and the second in the posterior portion of the temporoparietal scalp donor site. The implant is then placed in the correct anatomic orientation, axis, and projection on the mastoid area and draped with the TPF flap. Confirmation of correct position is key at this stage because the implant cannot be adjusted easily after the flap is placed under negative pressure. The radiograph template created at the beginning of the procedure is used at this time to ensure correct placement. If projection needs to be altered, some excess of the implant can be shaved off the undersurface of the fused implant, or soldered on to it if needed at the inferior aspect, for example, for greater projection in the setting of a severely hypoplastic sloping temporal bone. The flap is oriented with the loose areolar layer facing away from the framework and then loosely secured to the mastoid fascia with a 5-0 polydioxanone suture. Strong fixation of the framework to the mastoid is avoided to maintain mobility of the ear, a feature needed to help absorb trauma and



**Fig. 10.** (A) pHDPE implants come in 2 pieces to allow surgeons to adjust ear size as needed. There are slight variations by company on the shape of the preformed ear base, with some offering ready-made braces to buttress the helical rim (middle implant), as well as different arcs of curvature of the antihelical fold and the crura. (B) The 2 pieces are soldered together with ophthalmic cautery. (C) Further modifications using a scalpel can be done for optimization. (From Owen S, Wang T, Stephan S. Alloplastic reconstruction of the microtic ear. *Operat Tech Otolaryngol Head Neck Surg* 2017;28(2):100; with permission.)

resist framework fracture or soft tissue injury. If a native canal exists or a neocanal is being created during combined microtia-atresia surgery, then the implant position must be more fixated to the mastoid in order to avoid obstruction of the meatus by potential framework descent, even if it is subtle. A narrow strip of deep temporal fascia is raised and reflected through a window made in the base of the TPF serving as an inferiorly based



**Fig. 11.** Excess fragments of pHDPE such as shavings and amputated tragus/lobule component are used as material to reinforce the junctions between the 2 pieces. Finished product shows areas of reinforcement to prevent implant fractures. Helical root extension is amputated in cases with a canal or concurrent atresia surgery. Note that the implant is impregnated with iodine antiseptic solution. (A) Lateral surface of the implant; limited soldering or scalpel manipulation as possible (B) Medial (deep) surface of implant; primary area for soldering to reinforce. (From Owen S, Wang T, Stephan S. Alloplastic reconstruction of the microtic ear. *Operat Tech Otolaryngol Head Neck Surg* 2017;28(2):101; with permission.)

soft tissue sling. This fascial strip is wrapped around the inferior crus of the framework before covering the implant with the TPF flap.

The TPF flap is shrink-wrapped around the implant using negative pressure from the first drain. The second drain is for removal of any serous fluid from the TPF flap donor site (**Fig. 12**).

The anteriorly based skin flap is draped over the TPF, or amputated and positioned as a free skin graft. The lobule remnant typically requires inferior-posterior transposition, which is accomplished by sectioning it from the anteriorly based skin flap and transposing it based on a narrow anteriorly based pedicle (**Fig. 13**).

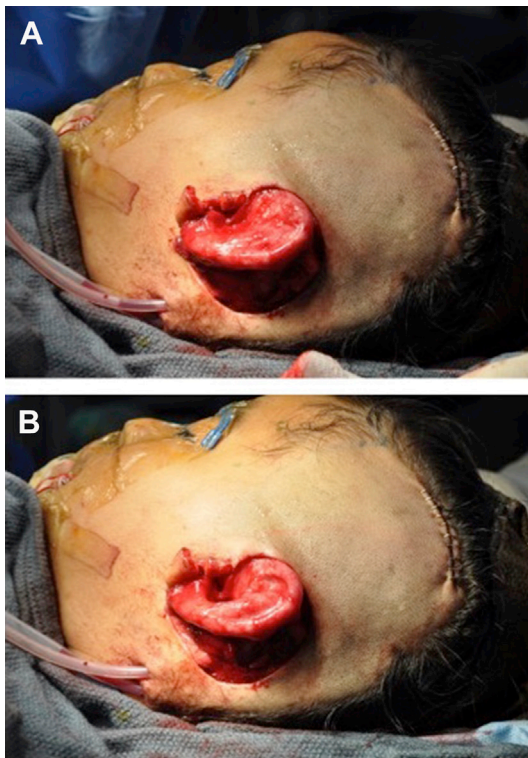
If the ipsilateral mastoid skin is not of sufficient surface area to cover the entire lateral surface of the new ear, a full-thickness skin graft is harvested from the contralateral postauricular sulcus. This graft provides the best color and texture match for the most aesthetically important parts of the reconstruction. A larger skin graft harvested from the inguinal region is typically required to cover the back of the ear. Care must be taken to adequately thin this graft, because it can be thick, even in children. Of note, the graft should also be

harvested as laterally as possible to prevent the inclusion of skin prone to grow pubic hair after puberty. Other donor site options include central lower abdominal skin, medial upper extremity, or supraclavicular fossa.

These harvested grafts are then combined to cover the new ear. The grafts will heal to resemble the original color and skin type from their donor regions. Because of this, the authors recommend that the ipsilateral auricular/mastoid skin be used on the lateral surface of the ear, with any gaps covered by the contralateral posterior auricular sulcus graft. The inguinal graft should be used primarily to resurface the new postauricular sulcus, because of its suboptimal color match. If possible, it is best to avoid inguinal skin anywhere on the helical rim, with the junction of the inguinal skin graft and the more favorable lateral surface grafts tucked behind on the medial surface of the auricle (**Fig. 14**).

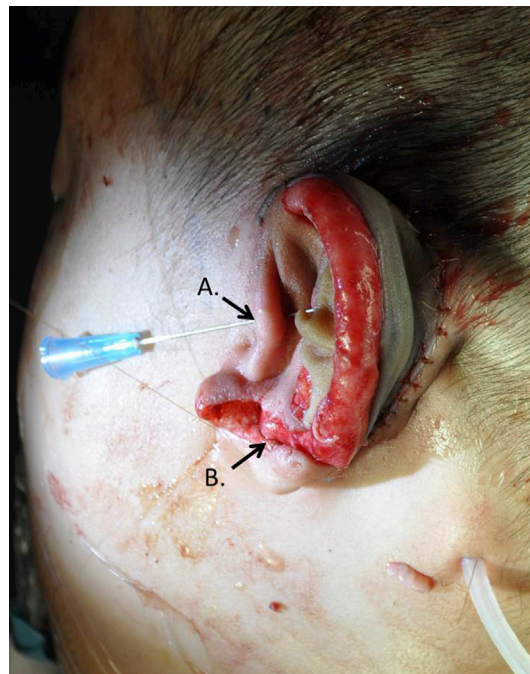
For those reconstructions requiring a tragus, a small amount of the remnant ear cartilage is tailored into a tragal graft. This cartilage graft is then covered by the anteriormost portion of the anteriorly based preauricular skin flap. If this flap needs to be amputated for preferred lateral





**Fig. 12.** (A) TPF flap draped over implant without suction. Anteriorly based skin flap has already been amputated. (B) Suction activated and flap shrink-wrapped around pHDPE framework. (From Owen S, Wang T, Stephan S. Alloplastic reconstruction of the microtic ear. *Operat Tech Otolaryngol Head Neck Surg* 2017;28(2):101; with permission.)

surface coverage, then a sufficient anterior portion is left attached to the preauricular skin to fold over a cartilage graft, braced temporarily with a needle, and secured using a 4-0 plain gut suture on a straight needle (see **Fig. 13**). Skin graft donor sites are closed, and skin grafts are attached to each other using absorbable gut suture. With the drains on suction, the auricle is coated with a thin layer of antibiotic ointment, gauze is tucked into concavities of the bowl, scaphoid, and fossa triangularis, and then the entire ear is covered in a custom silicone cast to prevent seroma, hematoma, or shearing trauma that may compromise skin graft viability during neovascularization. The silicone mold is secured to the scalp and skin with interrupted Prolene stitches. A Glasscock cup dressing is then applied to help prevent the weight of the silicone molding from pulling the auricle down. Pressure on the silicone mold should be avoided. Mastoid-style gauze pressure dressing is applied over the TPF donor site to prevent seroma formation.



**Fig. 13.** Neotragus can be made by securing a cartilage graft tailored from previously resected microtic remnant to the anteriorly based mastoid skin flap (point A). The lobule can be partially split to set back inferiorly and hold the inferior portion of the TPF-wrapped implant like a sling (point B).

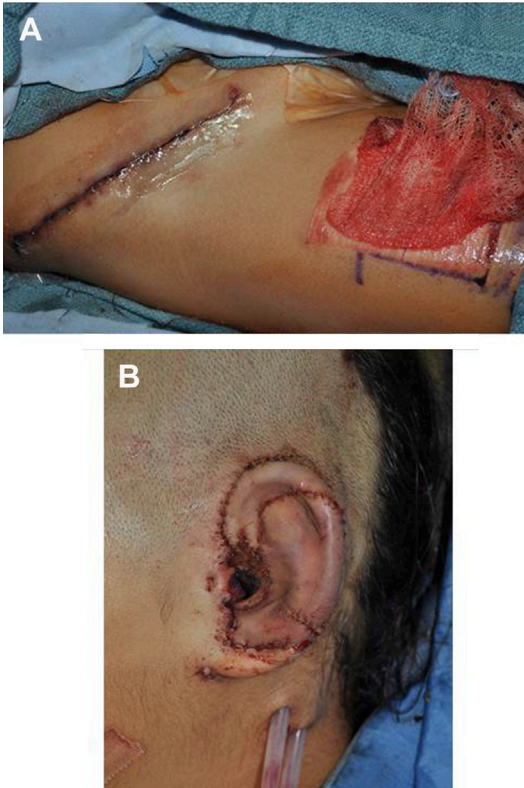
Immediately following extubation, all suction drains are removed (**Figs. 15** and **16**).

#### AFTERCARE

The gauze pressure dressing is removed after 3 days and the parietal region inspected for seroma. The silicone mold is removed in clinic at 11 to 14 days. A new silicone mold is created in clinic for use behind the ear to maintain projection and avoid sulcus blunting against the forces of wound contracture. Patients wear this all night for 4 months. The silicone should not be worn during the day as the weight of the mold can contribute to inferior descent of the ear. Parents are asked to sleep with their children in the bed for the first few weeks to ensure that they do not roll onto the reconstructed ear. Aquaphor, Vaseline, or other moisturizing ointment is used until the wound edges and grafts cease to crust or scab.

#### DISCUSSION

Despite the popularity of autologous rib, pHDPE remains an excellent framework reconstructive option for ear surgeons. The primary advantages remain the avoidance of chest wall donor site



**Fig. 14.** (A) Inguinal donor full-thickness skin graft (FTSG) donor site closed primarily. Medial thigh split-thickness skin graft donor site used to line new canal during combined atresia surgery. (B) FTSG cover TPF flap. Lateral surface of ear covered by combination of previously amputated ipsilateral mastoid skin flap, contralateral postauricular FTSG, and remnant lobule. Inguinal skin only used for medial surface. Tragal reconstruction completed with small piece of remnant microtic cartilage. Patient also underwent canal atresioplasty at the same time. (From Owen S, Wang T, Stephan S. Alloplastic reconstruction of the microtic ear. *Operat Tech Otolaryngol Head Neck Surg* 2017;28(2):102; with permission.)

morbidity, fewer stages, more consistent results, and the ability to perform an earlier repair. In most cases, this may be completed before the child starts school, minimizing the social impact of congenital deformity. Earlier repairs generally result in improved tissue healing and a more cosmetically appealing result.

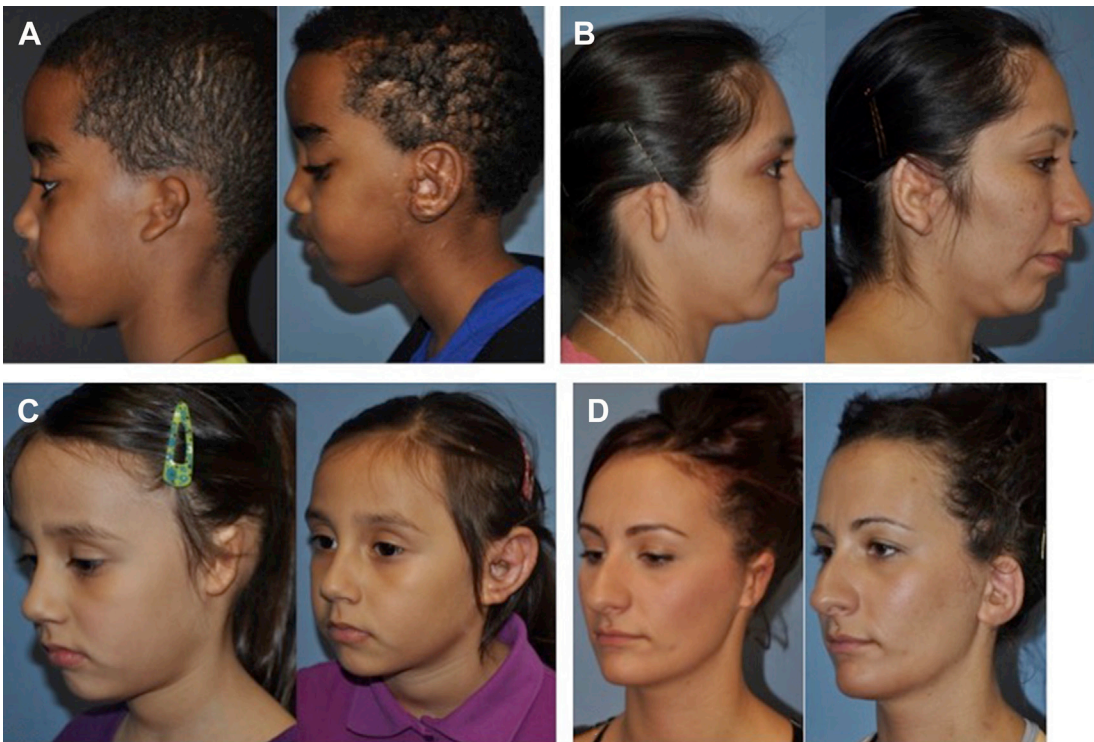
Although it is easy to focus on choice of framework material as the key ingredient for success, outcomes depend mainly on soft tissue coverage.<sup>4</sup> The use of tissue expanders to allow complete coverage of the implant with preauricular tissue has been described as a viable option



**Fig. 15.** Pink silicone mold covers the ear with a Glasscock cup dressing lifting mold slightly to support it. Gauze head wrap for pressure over TPF donor site. (From Owen S, Wang T, Stephan S. Alloplastic reconstruction of the microtic ear. *Operat Tech Otolaryngol Head Neck Surg* 2017;28(2):102; with permission.)

for soft tissue coverage. This technique has not been adopted by the authors because of the addition of an operative stage, potential tissue expander complications, the pain associated with expansion for children, and the fact that pHDPPE often becomes exposed under a skin flap unless it is covered by an intervening fascia flap.

The ability to perform an entire repair in a single stage results in less recovery time, repetitive exposure to anesthesia, and care by patients and families. Preformed pHDPPE implants allow less operative time carving rib frameworks, more predictability in the outcome, and an easier learning curve with respect to the framework design. However, microtia reconstruction in general requires meticulous attention to detail and superb soft tissue technique, regardless of what paradigm is used. As with any implantable material, there is concern for biofilm formation, infection, implant fracture, and extrusion. Although common in the early experience with pHDPPE, modern techniques have significantly improved complication rates, which are now comparable with those of



**Fig. 16.** (A, B) Primary reconstructions without canal atresia surgery. (C) Primary repair with combined atresia surgery. (D) Prior rib reconstruction revised with pHDPE approach. (From Owen S, Wang T, Stephan S. Alloplastic reconstruction of the microtic ear. *Operat Tech Otolaryngol Head Neck Surg* 2017;28(2):103; with permission.)

autologous rib techniques in experienced hands.<sup>4,12</sup> One study at a high-volume center examining long-term follow-up data elucidated no clear benefits to either autologous rib or pHDPE reconstruction.<sup>11</sup> Their conclusions were that pHDPE reconstructions had fewer operations and better size and contour match. Autologous rib advantages include better color match and decreased risk of extrusion.<sup>11</sup>

The senior author's experience implementing these changes over 28 years and their impact on rates of exposure, infection, and fractures is reflected in the notable trend toward reduced complication rate highlighted in **Table 1**. Several critical advancements in technique and materials that are responsible for this trend are discussed here.

## RELIABILITY OF POROUS IMPLANTS

Early implant trials attempted the use of multiple different materials. Silicone was favored initially for its ability to mimic the flexibility of the native ear cartilage, but high exposure rates ultimately left it undesirable.<sup>5</sup> Polyethylene has a long history of biocompatibility, and the addition of micropores allows for vascular and soft tissue ingrowth. This advancement dramatically

improved resistance to infection and exposure.<sup>19</sup> Romo and colleagues<sup>9</sup> reported a 4% complication rate in 250 cases over an 11-year period, and Austrian surgeons with 78 cases report an extrusion rate of 2.6%.<sup>20</sup> The senior author's own experience from 2008 to 2013 detailed in **Table 1** is very similar. Other smaller-volume studies report complication rates between 0% and 12%.<sup>10,11</sup>

**Table 1**  
Comparison of complication rates of porous high-density polyethylene ear reconstructions done by the senior author early in the series versus later in the series with implementation of several key technique advancements

	1993–1995	2008–2013
Procedures	25	487
Implant Fractures (%)	28	1.5–8.7
Implant Exposures (%)	44	4.3
Infections (%)	4	1.1

From Reinisch J. Ear reconstruction in young children. *Facial Plast Surg* 2015;31:601; with permission.

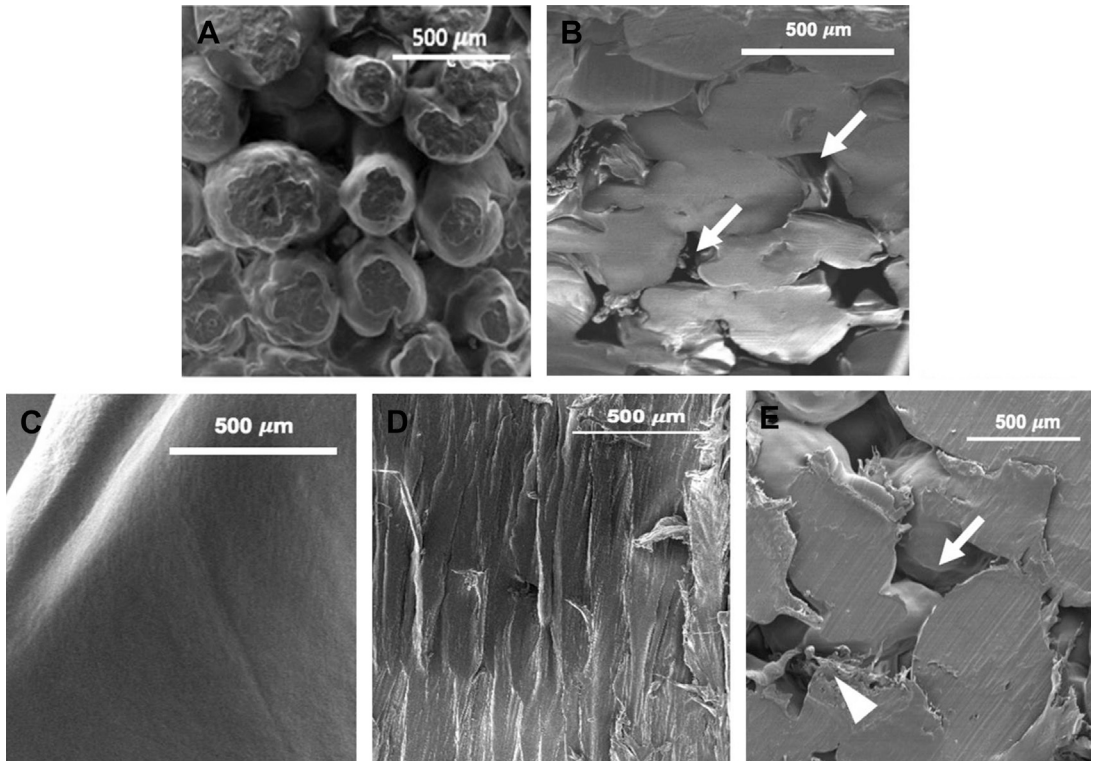
It follows that maintenance of the implant's porosity is important to the overall success, safety, and longevity of this technique. The junior author's preliminary investigations into this has yielded some interesting laboratory findings when analyzing electron microscopy images of pHDPE (Medpor samples) cut with a surgical scalpel as traditionally done, and compared with effects on porosity from soldering (as typically done for fusion of the 2-part implant), or sculpting the pHDPE with a drill using either a cutting bur or a diamond bur **Fig. 17**.

The overall porosity of the implant is decreased by any manipulation technique, but visual inspection shows only a modest decrease in porosity from baseline when pHDPE is cut with a scalpel, and only slightly worse than that when modified with a cutting bur using irrigation. However, all porosity seemed to be eliminated after soldering or diamond bur manipulation. Although the soldering is necessary to fuse the 2-piece implant together, minimizing the amount of soldering in the areas most prone to exposure is prudent. Clinical experience has shown the inferior portion of the helical rim where it fuses with the lobule

framework to be most vulnerable in this regard (especially in early recovery), because it is covered by the distal portion of the TPF flap and venous drainage must travel against gravity. Therefore, the safest technique to maintain porosity during framework modification is to use a scalpel and keep soldering to a minimum, and potentially only on the medial surfaces of the framework.

#### COVERAGE OF THE ENTIRE FRAMEWORK WITH THE VASCULARIZED TEMPOROPARIETAL FASCIA FLAP

In the early days of pHDPE ear reconstructions, only portions of the framework were covered with the TPF. The lower half of the implant was placed directly under the hairless mastoid skin, similar to how autologous rib reconstructions are now done. However, pHDPE requires more vascularized soft tissue coverage than autologous rib. In the early years, most exposures occurred at the sites covered under the mastoid skin inferior to the portion of the implant covered by the more vascularized fascia.<sup>21</sup> The dramatic decrease in exposure rate before and after this technical advancement is highlighted in **Table 1**.



**Fig. 17.** Electron microscopy of control and manipulated pHDPE samples (Medpor). Note that the porosity is altered in all forms of manipulation, but minimally with scalpel cuts, and modestly with a cutter drill with irrigation. Significant loss of porosity seen with soldering or diamond drilling. (A) Normal pHDPE (control sample). (B) After scalpel cut. Arrows show some residual porosity. (C) After soldering with ophthalmic cautery. (D) After diamond drill with irrigation. (E) After cutter drill with irrigation. Arrow indicates maintained porosity, arrowhead shows implant spicules.

### INCLUSION OF THE SUBGALEAL (AREOLAR) FASCIA WITH THE TEMPOROPARIETAL FASCIA FLAP

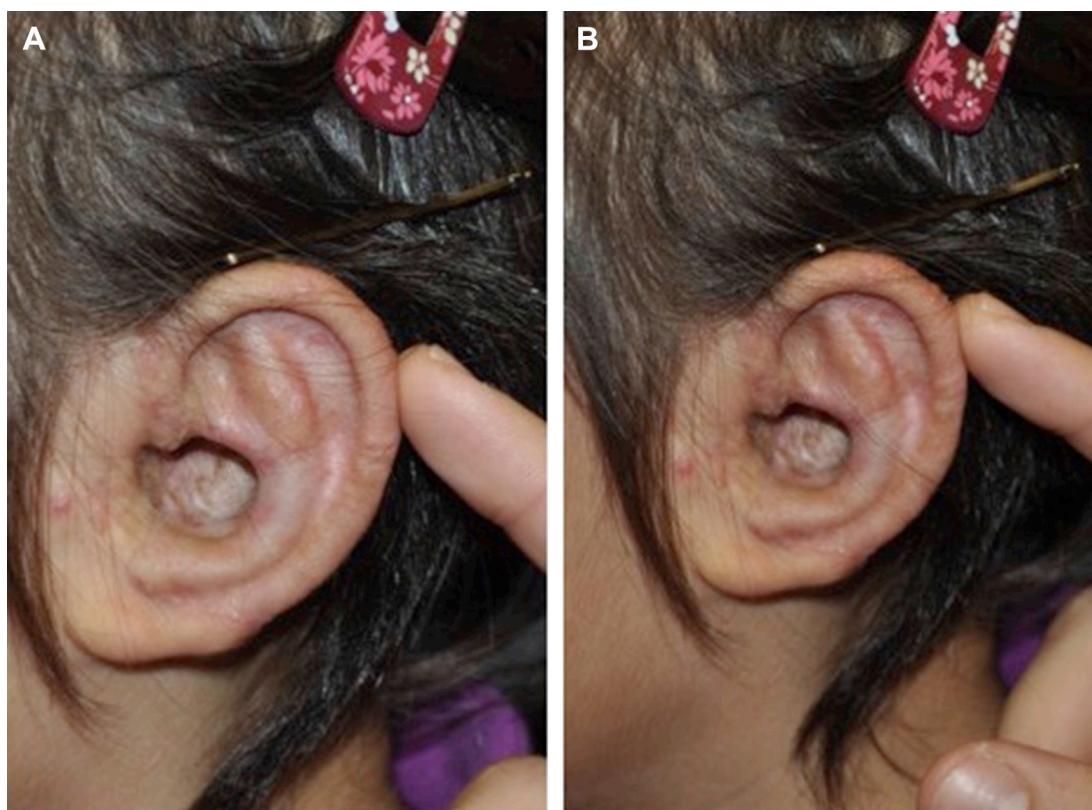
Traveling with the superficial temporal vessels is a sensory nerve making the TPF-covered ear implant sensate, a critical requirement for long-term viability and exposure prevention. However, if the overlying soft tissue is densely adherent to the implant, there is a much greater risk for exposure with normal auricular wear and tear. Over time the TPF undergoes tissue deposition and vascular ingrowth into the framework, which also makes it more adherent. Therefore, inclusion of the subgaleal loose areolar fascia with the harvest is important to avoid this problem. The loose areolar fascia is harvested off the superficial surface of the deep temporal fascia along with the flap. When transposed, this loose fascia now faces superficially and serves as a glide plane between the overlying skin grafts and the adherent TPF to resist soft tissue trauma and abrasion (Fig. 18).<sup>4</sup>

### REINFORCEMENT OF THE pHDPPE FRAMEWORK

In the senior author's experience, early breakage of the implant, from rates as high as 25% in the first few years of practice, encouraged reinforcement along the superior portion of the implant.<sup>21</sup> These modifications reduced the fracture rate to 1.5% of ears without canals and 8.7% in ears with canals in a total of 487 patients operated on between 2008 and 2013 with average follow-up of 1.5 years. Weak areas of the framework may be structurally bolstered by soldering the extra implant pieces carved off from the lobule or unused tragal extension to the weakest points of fusion using high-temperature battery cautery. The most critical area to re-enforce is between the superior crus and lateral helical rim.

### OCCIPITAL PARIETAL FLAP

Although the TPF is the ideal choice for primary reconstruction using a pHDPPE implant, another



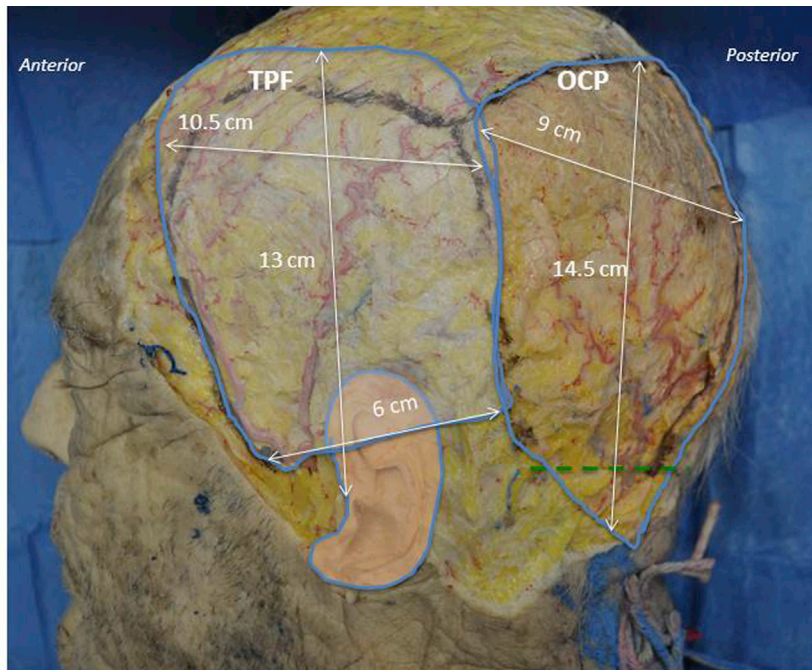
**Fig. 18.** Skin should be able to glide with the loose areolar tissue over the TPF flap, which is adherent to the pHDPPE implant. Notice how the skin envelope glides over the framework between images (A) and (B). This ability allows some degree of protection from abrasion and blunt trauma. The TPF flap carries sensory fibers and the resultant ear skin is sensate to fine touch. (From Owen S, Wang T, Stephan S. Alloplastic reconstruction of the microtic ear. *Operat Tech Otolaryngol Head Neck Surg* 2017;28(2):104; with permission.)

regional flap is available if needed:– the occipital parietal (OCP) flap based on the axial supply of the occipital artery and vein. Anatomically, the OCP flap is the superficial occipito-parietal fascia that is the posterior continuation of the TPF, all part of the epicranial aponeurosis (or galea aponeurotica). This flap can be used in the setting of revision after a failed TPF-based reconstruction using a pHDPE implant, serving as a plan B if problems occur. There are other scenarios in which an OCP flap is necessary: if the superficial temporal vessels or the TPF are compromised from prior scarring, burn, or surgery; when previously banked rib cartilage over the main STA bifurcation creates undue risk for vascular compromise or excessive flap thickness; if there is a malpositioned bone-anchored abutment for hearing appliances or prosthesis. The OCP flap is comparable with the TPF in thickness and pliability, also has a paired

sensory nerve with it, and typically yields similar aesthetic results to the TPF. However, the OCP flap harvest can be more challenging because it is further away from the mastoid region and requires a longer flap with more dissection below the nuchal line to allow for rotation and transposition (**Fig. 19**).

#### HARVEST OF A WIDE-BASED TEMPOROPARIETAL FASCIA FLAP

The TPF flap shows variability of both arterial and venous flow in up to 37% of patients.<sup>22</sup> The authors recommend the use of Doppler ultrasonography intraoperatively to confirm arterial supply patterns, and keeping as wide a base to the TPF flap as possible to improve venous and lymphatic outflow and inclusion of potential contributions from the posterior auricular, emissary, and



TPF Flap	Width (cm)	Length (cm) from canal
Min. size	8.5 (±0.47)	11.05 (±0.44)
<b>Recommend</b>	<b>10.5</b>	<b>12.5–13</b>

OCP Flap	Width (cm)	Length (cm) from 90° kink
Min. size	8.6 (±0.81)	13.05 (±0.55)
<b>Recommend</b>	<b>9</b>	<b>14–14.5</b>

**Fig. 19.** Latex-injected cadaver dissections show recommended dimensions of a TPF flap and an OCP flap. Vertical height for a TPF starts at the native conchal bowl or, in the case of microtia, the proposed conchal bowl. The TPF is transposed by flipping it down to the ear area like turning a page in a book. The OCP flap vertical height measurement begins approximately 1 cm below the nuchal line (*green dashed line*) where the main occipital vessels abruptly make a right-angle turn superiorly and penetrate the deep cervical fascia investing the trapezius muscle. The OCP flap is relocated to the ear area in a similar way as the TPF flip maneuver but also requires some rotation with the axis of pivot located at the nuchal line.

occipital vessels (see **Fig. 7**). Narrowing of the TPF pedicle base to include exclusively the main trunk of the superficial temporal vessels can be tempting intraoperatively, because the flap is much more mobile and can drape more easily over the implant with less potential folding in the sulcus area. However, this narrowing comes at the cost of the secondary vascularity provided from the mastoid region, which in our estimation is important to maintain.

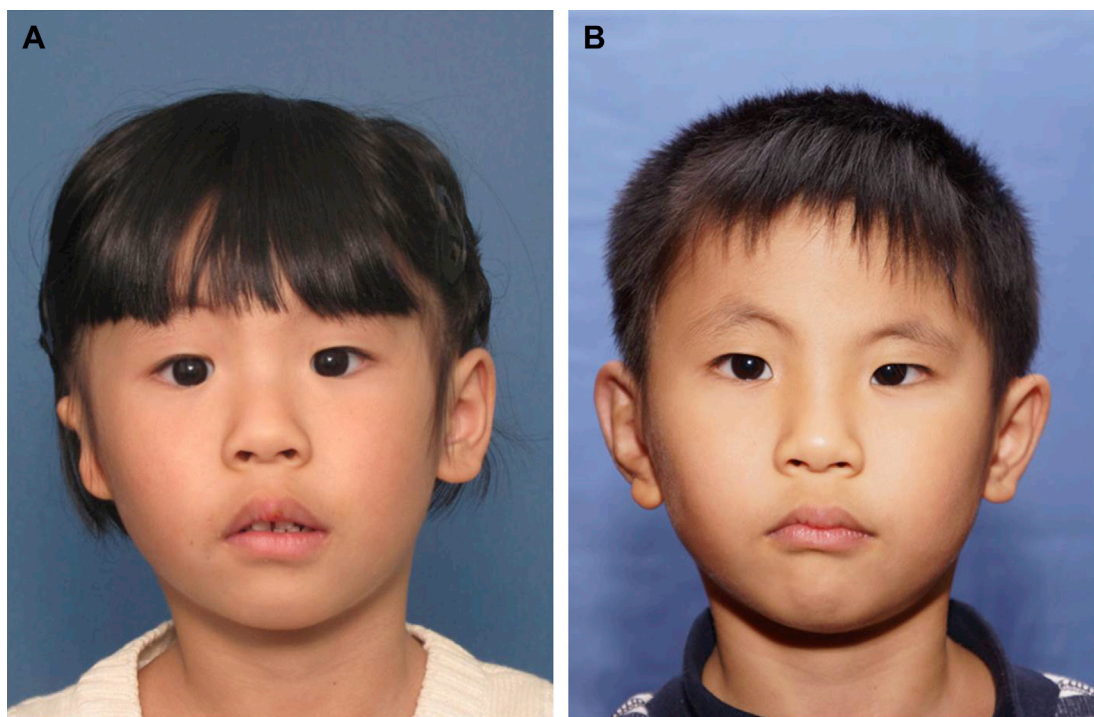
Cadaveric studies using latex injection of the galeal vasculature by these authors helped to corroborate the clinical experience on recommended flap dimensions used over the years (see **Fig. 19**). A pHDPE implant tailored to normative adult dimensions (implant sized to  $53 \times 31$  mm to accommodate additions of soft tissue envelope and lobule generating a  $60 \times 33$  mm adult ear of normative dimensions)<sup>18</sup> is covered by a raised TPF flap placed under negative pressure. The flaps were made smaller and smaller until minimum dimensions required to maintain a negative pressure seal were determined. This minimum size for both TPF and OCP flaps helped guide the recommendations listed in the table. These investigations also showed what portions of the TPF flap cover the different subunits of the auricular framework (**Figs. 20** and **21**). The inferior helical rim, midhelical rim, and antitragus are the locations that can have the highest risk for exposure over the long term. Verifying excellent vascularity of the flap

along these key locations and maintaining the secondary blood supply from the mastoid region can help prevent future problems.

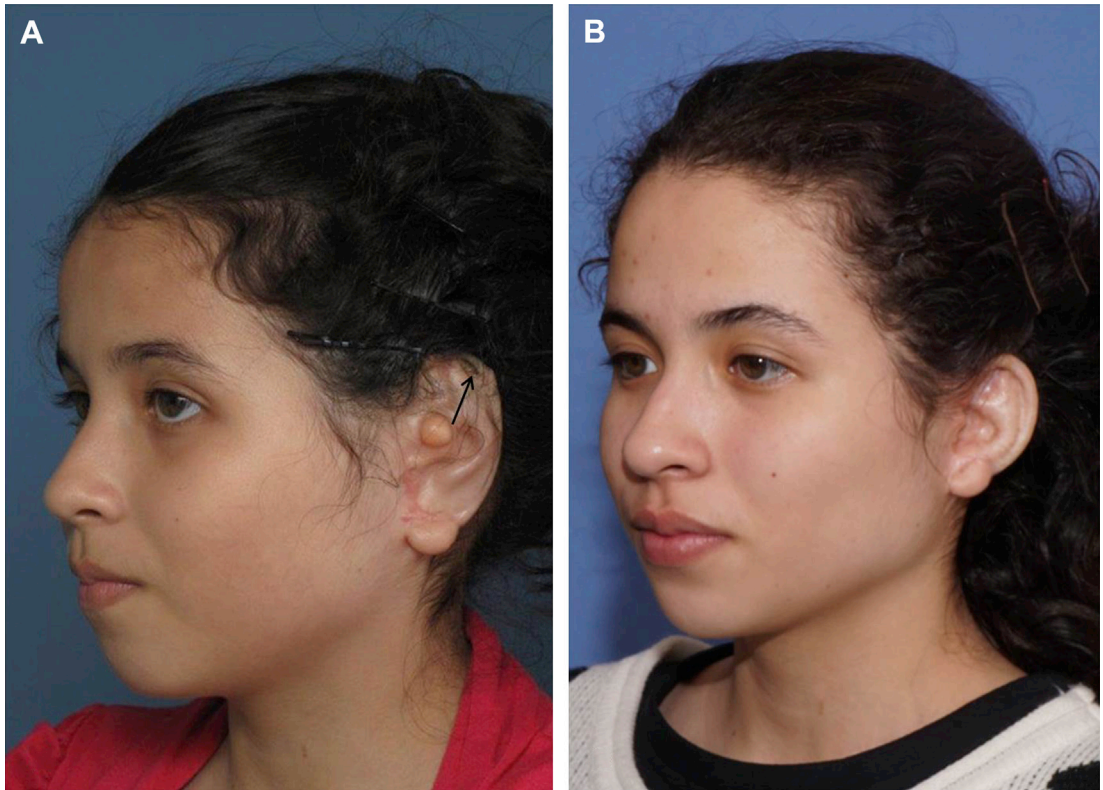
### FUTURE DEVELOPMENTS

Several exciting areas of innovation are emerging in alloplast-based auricular reconstruction. Customized implants made from computed tomography or MRI data of the contralateral ear offer the prospect of an identical match and have already been used in the setting of unilateral microtia. What remains to be seen is whether the significant increase in cost of creating this three-dimensional (3D) printed replica is balanced by a clearly demonstrable aesthetic improvement. Similar to rib reconstruction, the difference between a less than average result and an excellent outcome often depends not on the framework but on the soft tissue that is covering it. One advantage of the 3D customized implant is that it is a single structure not requiring fusion, which saves operative time and theoretically is stronger than the fused 2-piece implant.

Alloplast microtia frameworks may also have a role in stem cell-based auricular reconstruction. One of the great challenges facing rib microtia surgeons is the many inflammatory mediators and contractile forces that surround the autologous rib framework through the multitude of stages involved



**Fig. 20.** Single stage, outpatient pHDPE ear reconstruction. (A) Preoperative. (B) One year postoperative.



**Fig. 21.** Referral case with implant exposure following scalp tissue expander and placement of the implant under the expanded skin only. (A) Pre-op with arrow showing site of exposure at the helical rim. The STA was injured during the original placement of the expander. (B) Salvage done using occipital galeal flap (OCP) and replacement of the implant. Seen 3 years after OCP flap over new implant.

over time. These factors influence how much resorption may occur, leading to loss of detail, projection, and architecture. For those scientists trialing tissue-engineered auricular frameworks in animal models, these inflammatory and contractile forces often decimate the architecture and strength of the cartilage. pHDPE could be used as the primary stage, covering it with TPF and skin grafts in the standard fashion, while the chondrocytes harvested from the auricular remnant are cultured and prepared on scaffolds as many researchers have tried. The difference is that this bioengineered autologous cartilage framework could be swapped with the pHDPE implant in a second stage into a ready-made precontracted soft tissue envelope. The alloplast plays its part in bearing the brunt of soft tissue contracture and then makes way for an autologous, flexible framework to be inserted.

### SUMMARY

The use of pHDPE as an alloplast in microtia reconstruction offers an excellent framework for pediatric reconstructive surgeons. Advantages include earlier reconstruction, fewer procedures,

avoidance of donor site morbidity, shorter learning curve, and improved size and contour match. Results ultimately depend on soft tissue envelope, and choice of technique is best decided according to surgeon expertise and patient preference.

### REFERENCES

1. Im DD, Paskhover B, Staffenberg DA, et al. Current management of microtia—a national survey. *Aesthetic Plast Surg* 2013;37:402–8.
2. Owen S, Wang T, Stephan S. Alloplastic reconstruction of the microtic ear. *Operat Tech Otolaryngol Head Neck Surg* 2017;28(2):97–104.
3. Reinisch JF. Ear reconstruction with porous polyethylene implant—an 8 year surgical experience. Colorado Springs (CO): American Association of Plastic Surgeons; 1999.
4. Reinisch JF, Lewin S. Ear reconstruction using a porous polyethylene framework and temporoparietal fascia flap. *Facial Plast Surg* 2009;25(3):181–9.
5. Cronin TD. Use of a Silastic frame for total and sub-total reconstruction of the external ear: preliminary report. *Plast Reconstr Surg* 1966;37:399–405.



6. Berghaus A. Porecon implant and fan flap: a concept for reconstruction of the auricle. *Facial Plast Surg* 1988;133(1):111–20.
7. Wellisz T. Clinical experience with the Medpor porous polyethylene implant. *Aesthetic Plast Surg* 1993;17(4):339–44.
8. Spector M, Harmon SL, Kreutner A. Characteristics of tissue growth into Proplast and porous polyethylene implants in bone. *J Biomed Mater Res* 1979;13(5):677–92.
9. Romo T 3rd, Morris LG, Reitzen SD, et al. Reconstruction of congenital microtia-atresia: outcomes with the Medpor/bone-anchored hearing aid—approach. *Ann Plast Surg* 2009;62(4):384–9.
10. Yang SL, Zheng JH, Ding Z, et al. Combined fascial flap and expanded skin flap for enveloping Medpor framework in microtia reconstruction. *Aesthetic Plast Surg* 2009;33(4):518–22.
11. Constantine KK, Gilmore J, Lee K, et al. Comparison of microtia reconstruction outcomes using rib cartilage vs porous polyethylene implant. *JAMA Facial Plast Surg* 2014;16(4):240–4.
12. Long X, Yu N, Huang J, et al. Complication rate of autologous cartilage microtia reconstruction: a systematic review. *Plast Reconstr Surg Glob Open* 2013;1(7):e57.
13. Brent B. The pediatrician's role in caring for patients with congenital microtia and atresia. *Pediatr Ann* 1999;28:374–83.
14. Bradbury ET, Hewison J, Timmons MJ. Psychological and social outcome of prominent ear correction in children. *Br J Plast Surg* 1992;45:97–100.
15. Jiamei D, Jiake C, Hongxing Z, et al. An investigation of psychological profiles and risk factors in congenital microtia patients. *J Plast Reconstr Aesthet Surg* 2008;61(Suppl 1):S37–43.
16. Lee TS, Lim SY, Pyon JK, et al. Secondary revisions due to unfavourable results after microtia reconstruction. *J Plast Reconstr Aesthet Surg* 2010;63(6):940–6.
17. Park C, Mun HY. Use of an expanded temporoparietal fascial flap technique for total auricular reconstruction. *Plast Reconstr Surg* 2006;118(2):374–82.
18. Sforza C, Grandi G, Binelli M, et al. Age- and sex-related changes in the normal human ear. *Forensic Sci Int* 2009;187(1–3):110.e1-7.
19. Berghaus A, Axhausen M, Handrock M. Porous synthetic material in external ear reconstruction. *Laryngol Rhinol Otol (Stuttg)* 1983;62:320–7 [in German].
20. Kludt NA, Vu H. Auricular reconstruction with prolonged tissue expansion and porous polyethylene implants. *Ann Plast Surg* 2014;72(Suppl 1):S14–7.
21. Reinisch J. Ear reconstruction in young children. *Facial Plast Surg* 2015;31(6):600–3.
22. Park C, Lew DH, Yoo WM. An analysis of 123 temporoparietal fascial flaps: anatomic and clinical considerations in total auricular reconstruction. *Plast Reconstr Surg* 1999;104(5):1295–306.